

chambers at step **123104**, and based on preset levels air is added to increase combustion at step **123105**.

[0618] The second method shown in FIG. **124** involves providing a lower relative percentage of fuel, i.e. a normal fuel mixture which burns very hot in the combustion chamber and as it exits, the air provided via the air tubes, also called trim air, is used to manage e.g. cool the temperature of the hot gases entering into the heater chambers and provide some back pressure so that not as large a volume of hot combustion gases flow through a given hot gas channel into a specific heater chamber which is receiving additional trim air. The benefit of a richer combustion is that the cooler gases are less likely to damage the burner in the first method whereas in the second complete combustion method, there may be a decrease in efficiency because of the cold air input into the heater head center. In the second method shown in FIG. **124**, a fuel mixture is added at step **124101**, ignition occurs at step **124102**, hot combusted gases are circulated to the heater chamber **124103**, sensors measure temperatures in combustion and heater chambers at step **124104**, trim air is added to cool heater head and create back pressure in the heater chamber at step **124105**.

[0619] In either method, an important aspect of the invention is to maintain as equal a temperature across the four (4) heater heads **12203** with one flame, and hence in the heater chamber **12218**, as possible. Referring back to FIG. **122**, the control of the gas temperature entering each of the four (4) separate heater chambers **12218** of the burner **12205** can be individually controlled by directly controlling the temperature of the hot gas as in the second method, or controlling the combustion process as in the first method. The single burner is an important design because there is only a single flame, a single igniter, and few locations for a possible reliability issue.

[0620] Following heating of the heater heads **12203**, a substantial amount of the heat not used to heat the working fluid remains in the exhaust gases and thus the efficiency of the entire engine can be increased by using the exhaust gas heat to preheat the incoming air. The hot combustion gases pass from the hot gas channel **12242** into the heater chambers and after heating the heater heads and heater tubes therein, the hot combustion gases are forced out an exhaust inlet **12253** into the exhaust channel **12244** which is defined by the exhaust manifold wall **12243**. The exhaust passes down along the exhaust channel **12244** exchanging a substantial amount of heat through the manifold wall and into the incoming cold air entering the preheater **12226** via the preheater channel **12241**.

[0621] An insulation layer **12246** can be added around the entire burner between the heater chambers **12242** and the preheater **12226** to keep heat from traveling out of the combustion chamber into the preheater **12226**.

Restricting Flow

[0622] It is important to control the heat into each heater head to maximize the efficiency and power of the engine by maintaining the heads at very similar temperatures. Moreover it is important to recognize that the engine is limited to a highest operating temperature by the heater head material properties. In other words, the heater heads, or any particular heater head, cannot exceed the highest operating temperature. By way of example if one heater head is operating at the highest operating temperature, in the single burner embodiment described above the fuel flow cannot be

increased to the engine to increase the temperature of the other heater heads. The hotter heater head must be cooled. The control of the flow of hot combustion gases past each heater head can be controlled by the methods using the rich and lean combustion and trim air described above. Alternatively, another method of controlling the gas temperature applied to the heater heads shown in FIGS. **125A**, **125B** and **126**, provides a flow of non-combustion gas (e.g. air) through an air intake **12536** into the bottom of each heater head adjacent the cooler plate **12525**.

[0623] There is a non-combustion gas supply for each heater head as shown in FIG. **125A**. An inlet **12536** supplies the non-combustion cooling gas to a supply line **12538** brazed to the outside of the burner base assembly **12540** and includes an elbow **12542** to get around the corner while occupying minimal space. The supply line **12538** terminates at a flow diverter ring **12544** which is located at the base of the heater head **12503**. The flow diverter ring **12544** has by way of example, twenty 0.100" diameter holes **12546** which create a restriction for any cooling gases supplied to the heater head to eventually escape toward the exhaust outlet (not shown) through the holes **12546**. When the diverting air is supplied through the supply line **12538** to cool a heater head **12503**, the hot combustion gases meet an increased resistance at that particular heater head and the remaining heads will experience a greater mass flow since they provide less resistance to the incoming hot combustion gases. As a result, the amount of heat transfer—and therefore temperature—is decreased for the particular heater head to which diverting air is supplied. The burner base assembly **12540** with cooling gas supplies lines **12538** is shown in FIG. **125B**.

[0624] Additional flow of air or other non-combustion gas, i.e. the restricting flow, at the bottom of each heater head, although the flow can enter at other locations relative to the heater head as well, creates a back pressure in the heater chamber **12518** which restricts the amount of hot exhaust gases which can pass next to the heater head. The flow diverter ring **12544** directs the cooling gas into the heater chamber and essentially merges the colder restricting gas or air with the hot exhaust gases attempting to exit the heater chamber **12518** into the exhaust. As discussed above, the cool non-combustion gas provides the additional benefit of cooling the hot heater head in addition to providing a back pressure which restricts the amount of hot combustion gases entering into the heater chamber **12518**.

[0625] When restricting non-combustion gas, or air for example is applied in this manner to the heater head **12503** which is too hot, the combustion gases meet an increased resistance at the particular head and the remaining heads will experience a greater flow of combustion gases since they provide less resistance. As a result, the one hot heater head decreases in temperature and the other heads will increase in temperature, thereby decreasing the difference in temperature between the heads and allowing an increase in fuel flow so a higher average temperature can be sustained. A suitable control system should allow a very close temperature tolerance between all the heads and provide maximum temperatures at each head to be essentially equal. As a result, efficiencies can be maximized.

[0626] A control scheme is shown in FIG. **126** for controlling the addition of restricting non-combustion gas to provide cooling and/or restrictive flow to the heater chambers **12518**. A flow controller FC is modulated to control the